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REPORT

'CARFAX' traffic information service: requirements for the receiver

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'CARFAX' TRAFFIC INFORMATION SERVICE: REQUIREMENTS FOR THE RECEIVER

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Summary

This Report discusses the design requirements for receivers for the proposed BBC 'CARFAX' Traffic Information Service. Reference is made to a BBC prototype receiver design which serves as an example.

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'CARFAX' TRAFFIC INFORMATION SERVICE: REQUIREMENTS FOR THE RECEIVER

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1. Introduction

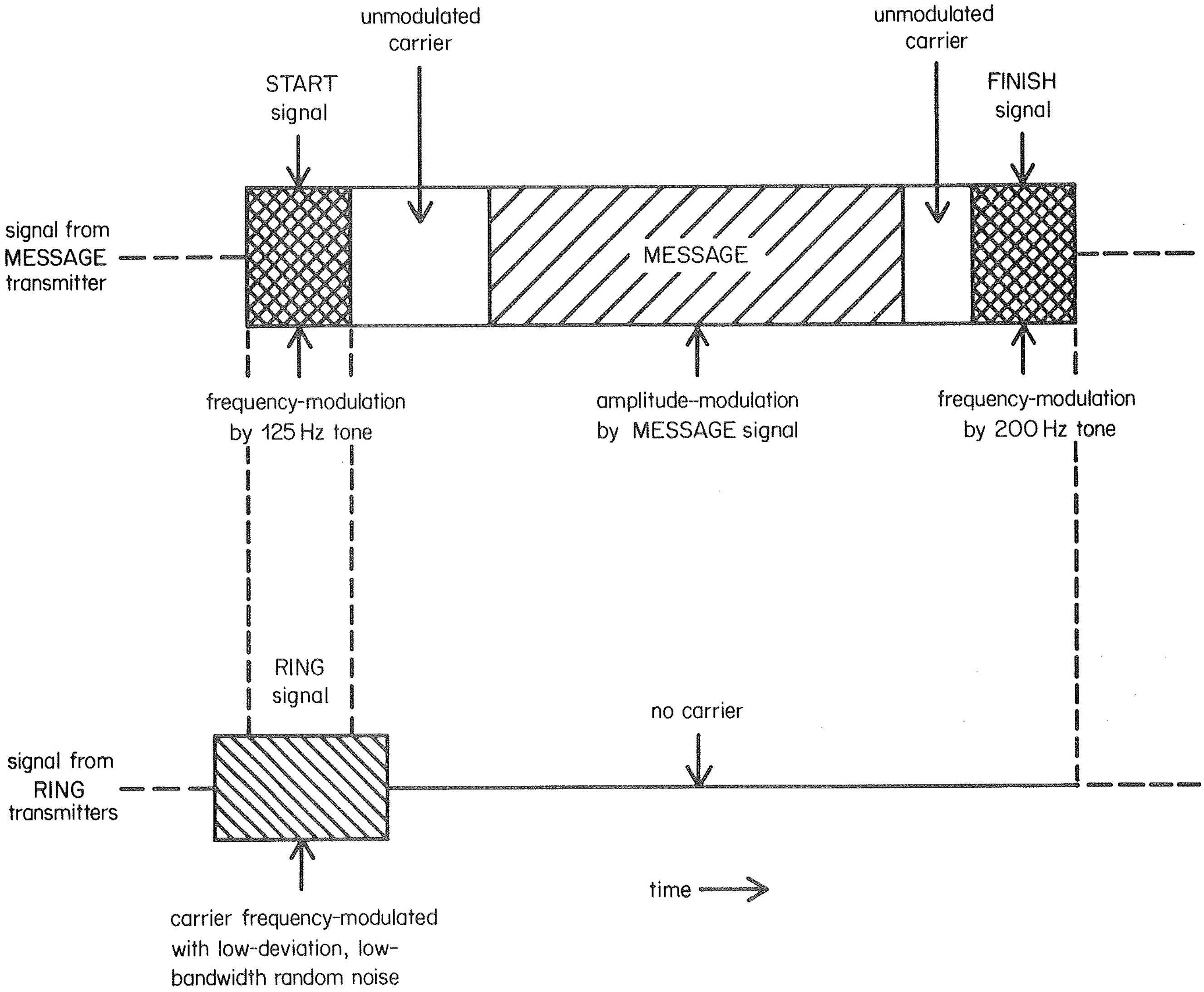
The BBC 'CARFAX' proposal[1,2,3] for a Traffic Information Service in the UK will provide road users equipped with a special 'CARFAX' receiver with spoken traffic messages appropriate to their local area.* It is planned to use a dedicated network of about eighty low-power transmitting stations to cover the UK using a common frequency around 500 kHz and operating on a time-sharing basis.

A dedicated traffic information service of this kind enables the motorist to choose one of three main listening options:

(i) ordinary listening without interruptions by traffic announcements; the ordinary listening may be from a conventional car radio receiver, tuned to any frequency, or a cassette player, etc.

(ii) ordinary listening, as above, interrupted by local traffic announcements when they are received.

(iii) traffic announcements only, with silence in between.



unmodulated carrier
START signal
unmodulated carrier
FINISH signal
signal from MESSAGE transmitter
MESSAGE
frequency-modulation by 125 Hz tone
amplitude-modulation by MESSAGE signal
frequency-modulation by 200 Hz tone
RING signal
no carrier
signal from RING transmitters
carrier frequency-modulated with low-deviation, low-bandwidth random noise
time

Fig. 1 - Sequence of events during a 'CARFAX' message transmission

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* Of course, long-range strategic information can also be provided.

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The primary consideration in the development of the proposed service was that of simplicity and low-cost in the receiver. This Report discusses the technical requirements of the receiver showing how this has been achieved. Reference is made to a BBC prototype unit and an outline of the receiver performance requirements is included as an Appendix.

The parameters quoted in the Report, both for the transmission system and for the receiver, apply only to the field trial schedule to begin in 1979. Certain changes may be recommended in the light of experience gained from the field trial, but such changes will probably be of only a minor nature.

2. The start and finish signals

Each 'CARFAX' transmitter radiates only when messages are to be broadcast in the area it serves. The format used for the transmission of each message is shown in Fig. 1. A transmitter first radiates a coded 'START' signal, which consists of a burst of 125 Hz sinusoidal tone which frequency-modulates the carrier to a peak deviation of ±2 kHz. This signal is used to activate 'CARFAX' receivers for the reproduction of the message that follows. The message signal speech modulation is band-limited to about 3·5 kHz, pre-emphasised to 150 μs and highly compressed; it amplitude-modulates the carrier to a peak depth not exceeding 95%. Finally, a 'FINISH' signal is radiated which is used to de-activate receivers, after which the transmitter is turned off. The FINISH signal consists of a burst of 200 Hz sinusoidal tone, again frequency-modulating the carrier to a peak deviation of ±2 kHz.

The reception of messages from a given transmitter is constrained to a well-defined service-area by effectively 'jamming' or inhibiting the reception of the START signal outside that area.[2,4,5] This is achieved by causing each of the surrounding ring of transmitters* to radiate what is effectively plain carrier for a period that 'straddles' the START signal; the ring transmitters remain off for the remainder of the sequence as shown in Fig. 1. The boundary inside which successful reception of the START signal is possible and outside which reception is inhibited by the ring signal is very abrupt due to f.m. capture effect.[4,5] Capture effect, here, results in the demodulated signal at the receiver being predominantly determined by the modulation of the stronger input r.f. signal, even though the levels of the two r.f. signals may not be very different; using the parameters chosen, f.m. capture effect is very pronounced, a 20 dB change in demodulated START tone level resulting typically from a 2 dB change in the level of an interfering ring (c.w.) signal. When the receiver fails to recognise a START signal because of the inhibiting action of a ring signal, it does not become activated and the message which follows is not then heard.

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* Throughout this Report, a transmitter operating in the inhibiting or jamming mode is described as a 'ring transmitter' and the signal it radiates is described as a 'ring signal'. In its other role, it is described as a 'message transmitter' when it radiates the sequence of signals shown at the top of Fig. 1.

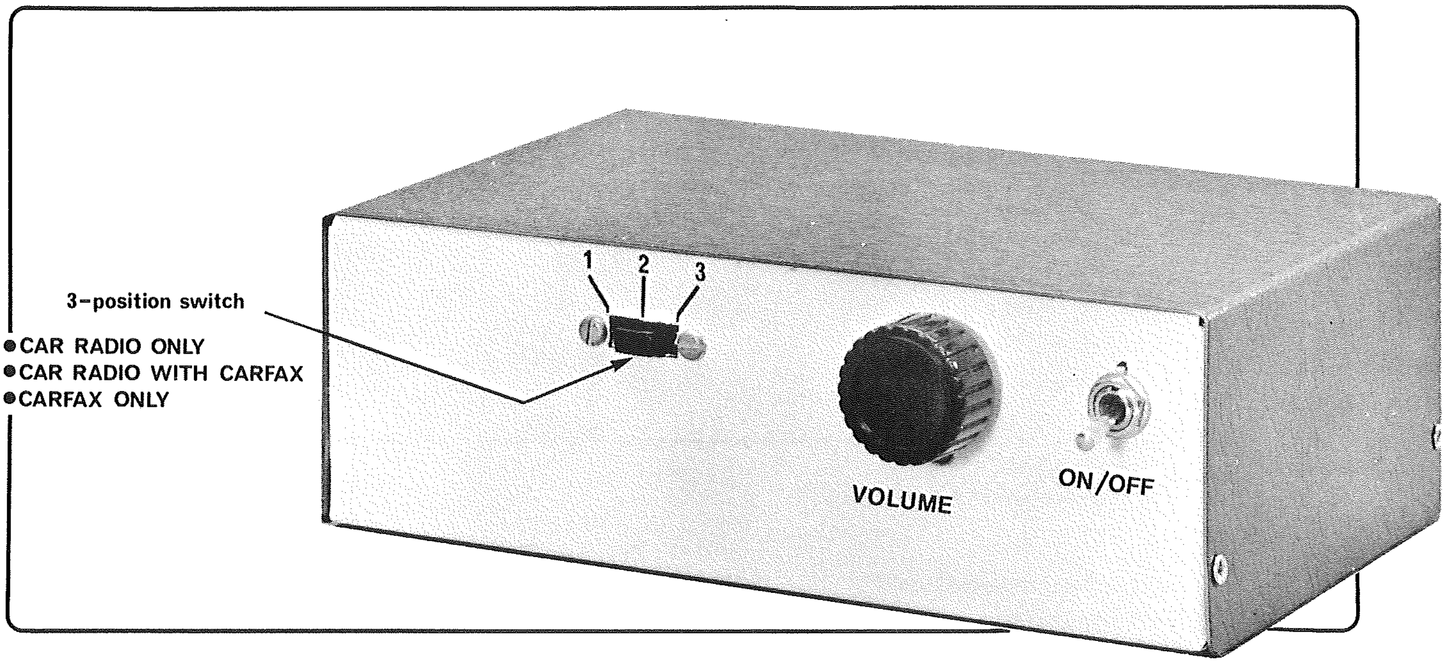

Fig. 2 - An experimental self-standing 'CARFAX' receiver

The use of frequency-modulation with a high modulation-index is also advantageous in the case of the FINISH signals, which penetrate severe interference and operate down to very low field-strengths. This property minimises the irritation to users that would otherwise be caused by receivers being inadvertently left in the activated state.

3. Outline of receiver

The 'CARFAX' receiver may be packaged in various forms. Fig. 2 shows an experimental self-standing receiver which can operate by itself or in conjunction with an existing car radio receiver, or cassette player, etc. A receiver of this kind may or may not have the facility for interrupting the motorist's ordinary listening. Two examples of a second form of receiver are shown in Figs. 3 and 4. These prototype receivers were manufactured commercially and are known as 'integrated' receivers because they combine the functions of a conventional radio with 'CARFAX' reception, all in the same case. The three-position switch on each receiver allows selection of the three listening options listed in Section 1. A third application might be in domestic portable receivers; 'CARFAX' modules could be fitted into otherwise ordinary radio sets in the same way as into car radios. This could be an important aspect of the service, for example for breakfast-time listening, whereby information would become available to road users while they were still at home.

The prototype 'CARFAX' receiver circuit board, which is described later in Section 5, is shown in Fig. 5 with a conventional car radio for comparison. However, it is thought that, using modern technology, the size of the 'CARFAX' module could be reduced to a fraction of that shown. The cost of including such a module in a conventional car radio is difficult to estimate but, with mass-production, a figure of £10 is thought to be realistic. A self-standing 'CARFAX' receiver might well cost more because of the need for a separate case and a loudspeaker-amplifier, although this would be offset to some extent by its independence, for example, in the input circuits. The idea of a very simple, independent receiver that could be fitted close to the driver is growing in favour with some manufacturers.

Receivers are fixed-tuned to the common

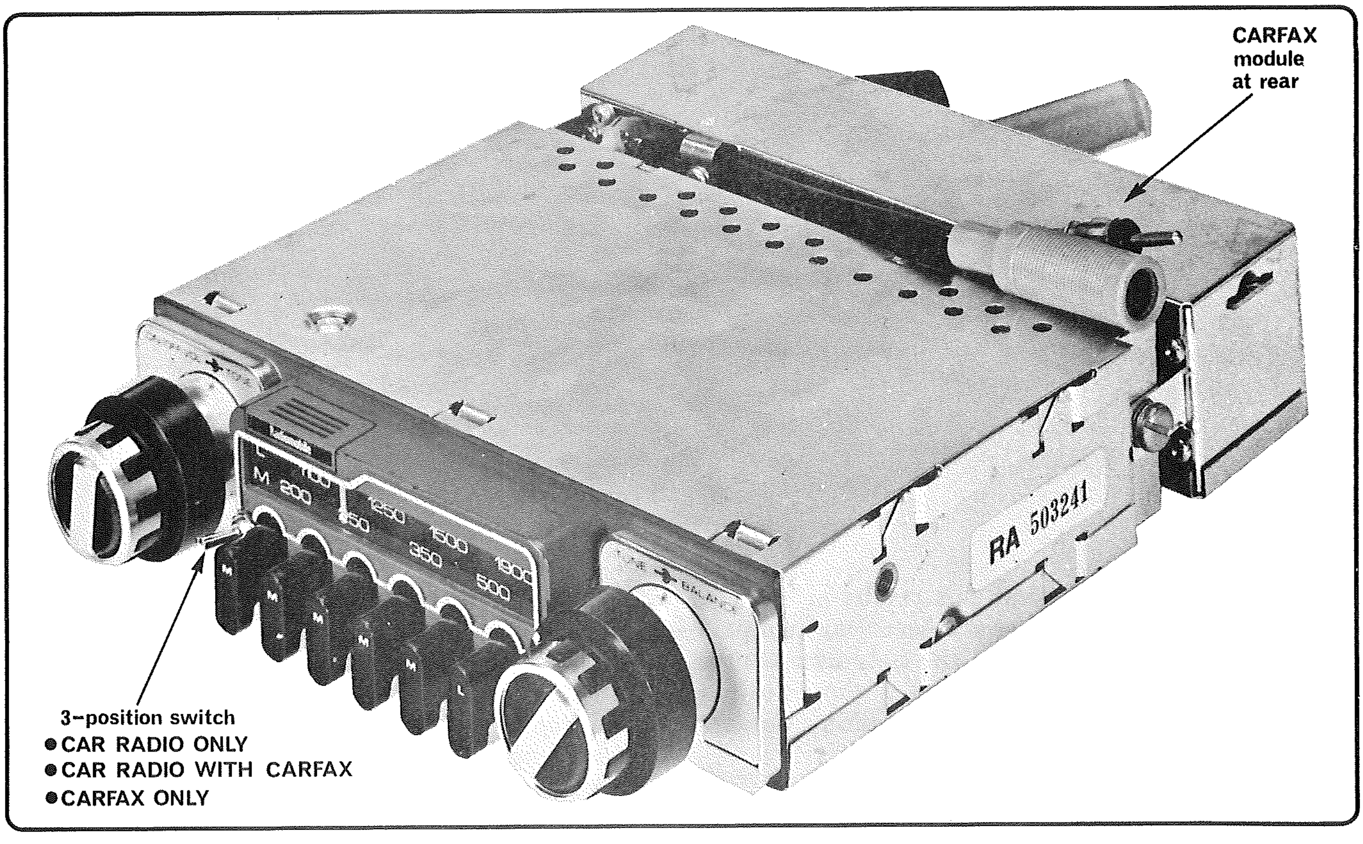

Fig. 3 - A commercially made prototype integrated unit combining a conventional radio receiver with a 'CARFAX' receiver (in rear housing). The toggle switch to the left of the push buttons controls the 'CARFAX' receiver

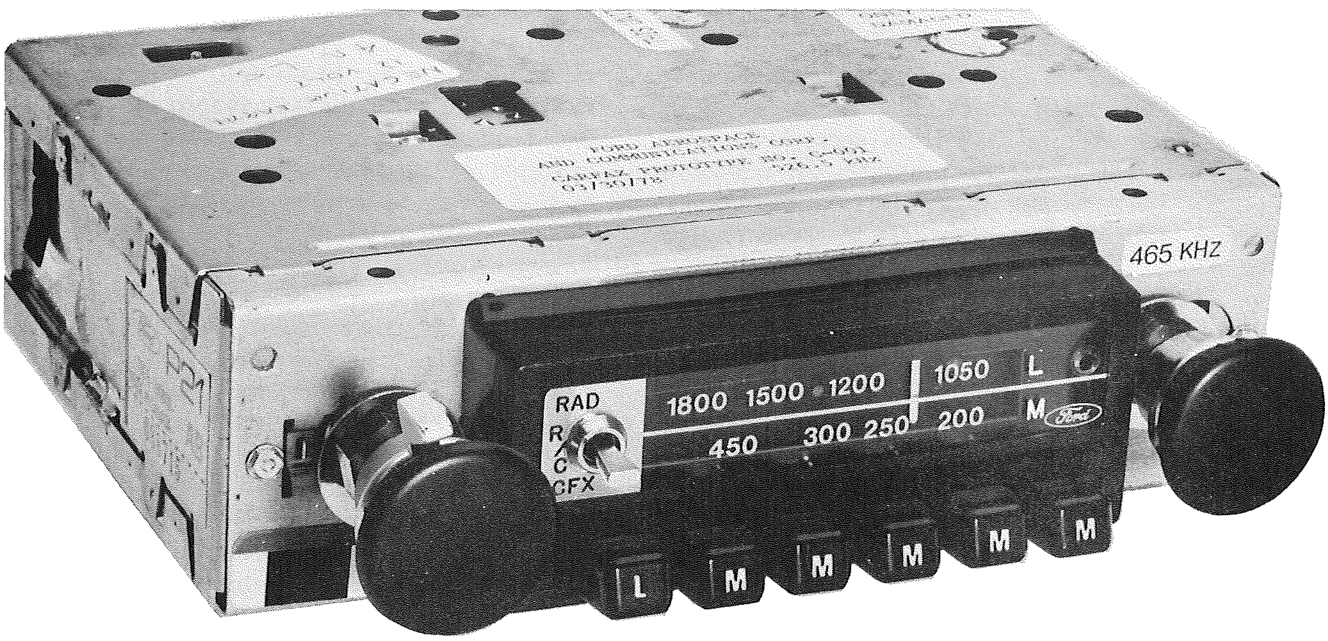

Fig. 4 - A commercially made prototype integrated unit combining a conventional radio receiver with a 'CARFAX' receiver in the same housing

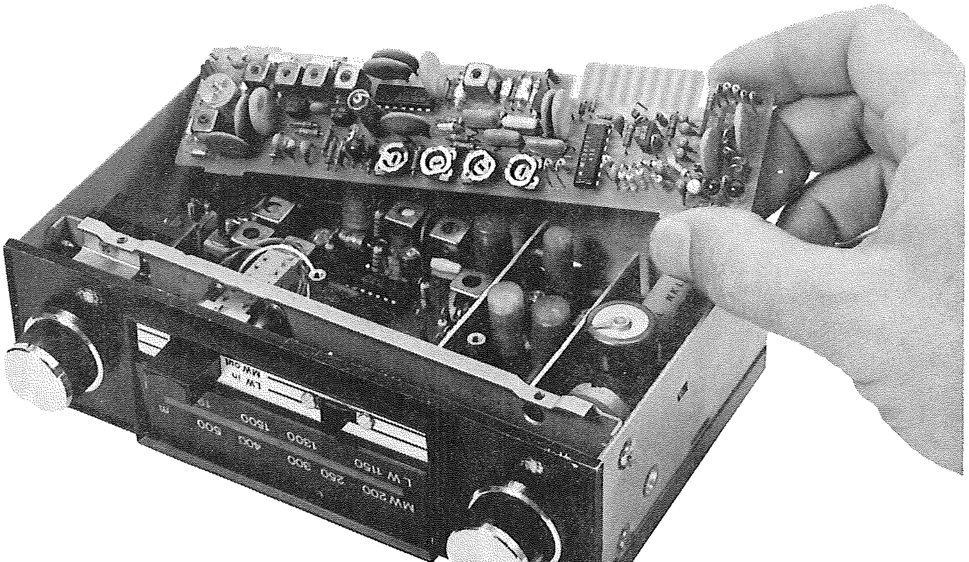

Fig. 5 - The prototype 'CARFAX' receiver circuit board held above a typical conventional car radio receiver for comparison

'CARFAX' frequency and this results in low cost and simplicity. The receiver needs no manipulation by the driver – indeed the only user control necessary is an on-off switch (or three-position switch as described above), and a volume control, where this is considered desirable.

The following sections describe the operation of the receiver in more detail and discuss various aspects of its design and performance. An outline of receiver performance requirements is reproduced as an Appendix (Section 9).

4. Functional description of receiver

The operation of the receiver can be subdivided functionally as shown in Fig. 6. The aerial splitter shown in this figure allows a single aerial to feed both the 'CARFAX' receiver and a conventional car radio receiver.

The carrier frequency, both for the field trial and for a future 'CARFAX' service will be located in the low-frequency part of the m.f. band and, at these frequencies, a straight tuned-radio-

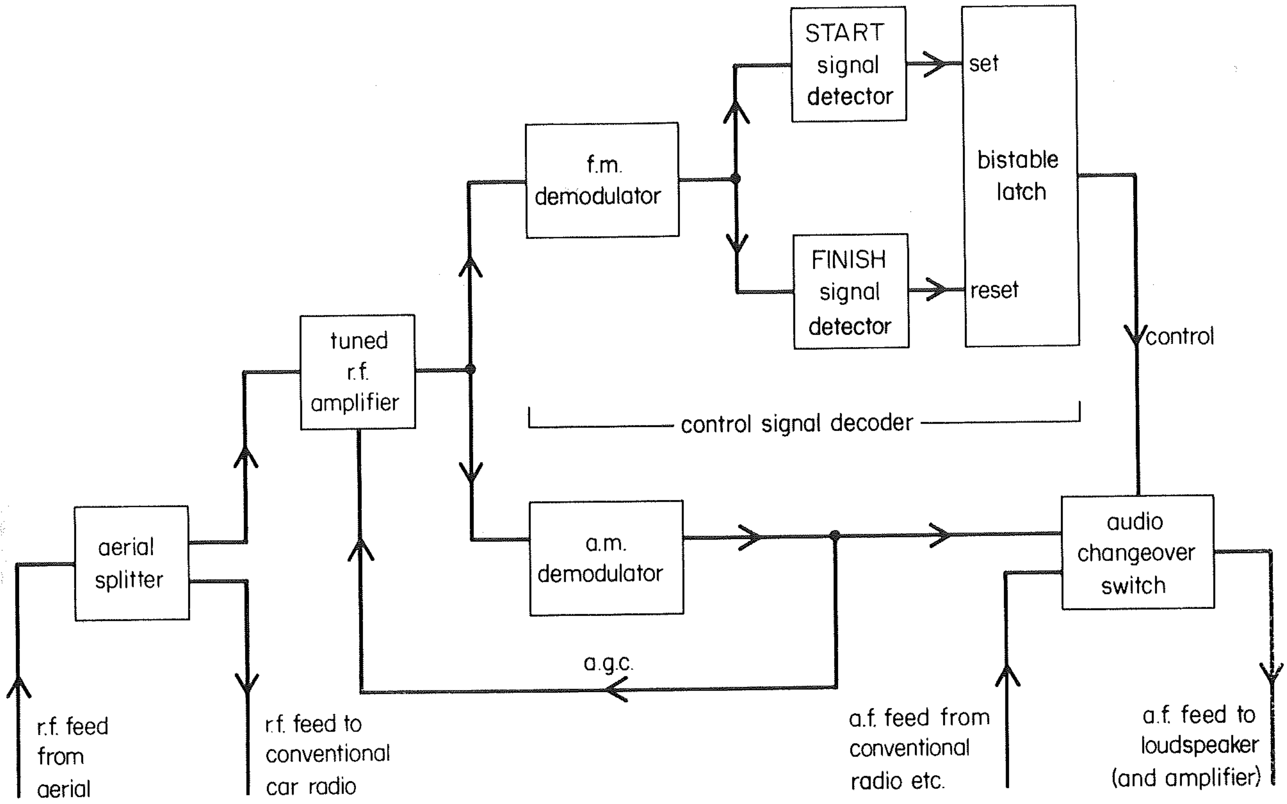

Fig. 6 - Functional block diagram of the 'CARFAX' receiver

frequency (t.r.f.) receiver as shown in Fig. 6 is feasible, with a consequent avoidance of the interference that might be created by a local-oscillator if a superheterodyne system were used. Both a.m. and f.m. demodulators are required, the former for the message, and the latter for the START and FINISH signals. The output of the f.m. demodulator drives START and FINISH signal detectors which can each consist of an active bandpass filter and a level-detection circuit. When a START or FINISH signal is successfully received a bistable latch is set or reset, respectively, and the state of this latch determines the position of an audio changeover switch.

The audio changeover switch selects either the output of the a.m. message demodulator (when the receiver is activated) or the audio feed from a conventional radio receiver, etc. (when de-activated). The changeover from ordinary listening to the traffic announcement can be in the form of a cross-fade, to avoid sudden programme changes. It should be possible to override the receiver manually, for example by action of the three-position switch already mentioned.

5. The prototype receiver

The prototype serves to illustrate the operation of a typical 'CARFAX' receiver. The complete circuit diagram of this receiver is shown in Fig. 7; the upper half of the diagram comprises the fixed-tuned r.f. amplifier, message demodulator and audio circuits, whilst the lower half shows the control signal decoder. The particular circuit shown is intended to be integrated with a conventional car radio receiver circuit.

The aerial splitter is a passive circuit based on a balanced capacitive-bridge network. The act of trimming the aerial (which is carried out in the usual way by adjusting for maximum audio signal output with a weak r.f. input signal) ensures that the bridge is balanced, in which case the two output ports become isolated from each other. One output is broad-band and has a capacitive output impedance, which suits a conventional car radio input circuit, whilst the other output can be tuned by the primary inductance of T2 to the 'CARFAX' carrier frequency. The purpose of T1 is simply to pass v.h.f. signals from the aerial to a conventional car radio receiver with minimum loss. A more detailed description of the aerial splitter circuit is given in Appendix II (Section 10.2).

The receiver is of the t.r.f. type, and transistors X1 to X3 provide r.f. amplification under the control of an a.g.c. signal provided by the envelope-detector diode D1. R.F. selectivity is

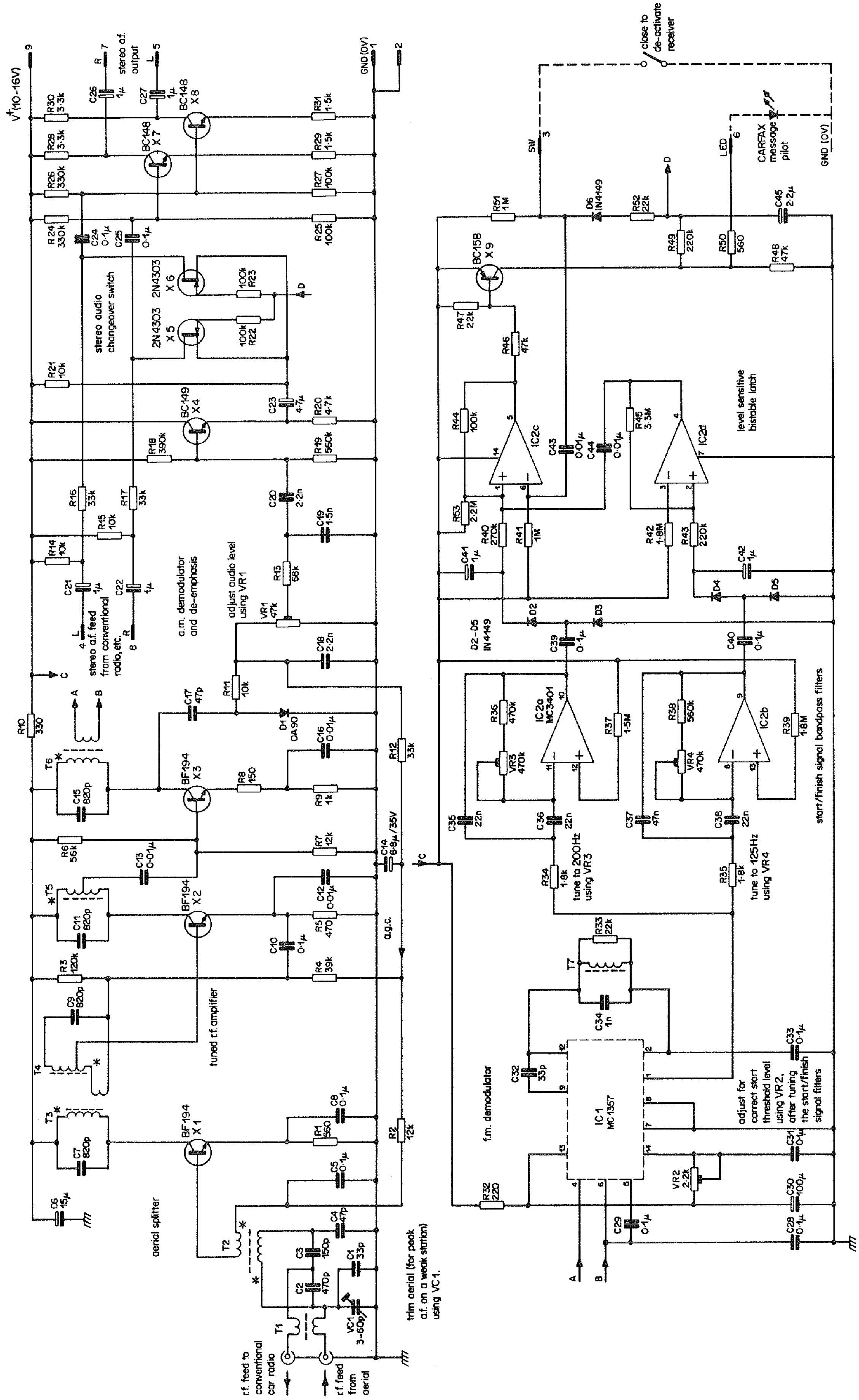

Fig. 7 - Circuit diagram of the prototype 'CARFAX' receiver

provided by four tuned-circuits which use conventional i.f. coil assemblies (T3 to T6) and which are each tuned for maximum output at the 'CARFAX' carrier frequency. Winding details for the coil assemblies are given in Appendix II (Section 10.1). The envelope-detector also provides the demodulated audio (message) signal, which is passed via a de-emphasis circuit to the audio changeover switch.

The r.f. signal prior to envelope-detection is sampled by the secondary winding on T6 and fed to a conventional f.m. demodulator integrated circuit IC1. This comprises a limiting section and a quadrature discriminator. A gain control VR2 is provided to vary the demodulation sensitivity.

The START and FINISH signal detectors are active bandpass-filters at 125 Hz and 200 Hz, respectively, followed by quasi-peak detectors and a level-sensitive latch. The filters have a design Q-factor of about 10, and are tuned by VR3 and VR4 (see Fig. 7). The provision of a pre-set tuning adjustment permits low-tolerance components (±10%) to be used in the filters. The level-sensitive latch is made up of a Schmitt trigger comprising IC2d which gives positive indication of the presence of START tone, and a bistable IC2c. The bistable is set on the falling edge of the START tone burst by a negative-going pulse delivered via C44. It is reset as soon as a FINISH signal is detected, or manually by taking the connection marked 'SW' to ground (OV). The circuit, as shown, allows the latch to become set once again by a subsequent message even though the manual switch is in the 'de-active' position ('SW' to ground) – this causes a warning pilot lamp to light but will not allow the audio changeover switch to interrupt the user's ordinary listening unless the manual switch is released. Note that the wiring of a three-position switch is not shown.

The latch controls the audio changeover switch via the low-pass filter R49/C45 to give a cross-fade between the feed from a conventional radio receiver, or other audio source, and the message signal. The audio changeover switch can handle a stereo signal-pair and each channel uses a field-effect transistor (X5 and X6) as a variable resistance element. In the de-activated condition, these elements are effectively open-circuit and the stereo signals are not affected. On reception of a START signal, the receiver becomes activated and the drain-source resistances of X5 and X6 decrease to typically less than a hundred ohms. In this state, the stereo signals are attenuated by the ratio of this resistance to R16 and R17, the output impedance of the emitter-follower X4 being low, and are each replaced by the 'CARFAX' message signals. The output impedance of the switch is high, and transistors X7 and X8 provide buffer amplification to give a lower output-impedance.

Several receivers have been constructed to this design and were each found to perform within the outline requirements quoted in Appendix I (Section 9). The receiver circuit shown in Fig. 7 could be adapted for use in a 'self-standing' type of 'CARFAX' receiver by the addition of loudspeaker amplifiers and a volume control, etc.

6. Aspects of receiver design

This section outlines some important aspects of the design of 'CARFAX' receivers.[6] The outline receiver performance requirements given in Appendix I (Section 9) were drawn up from considerations such as these and in liaison with car radio receiver manufacturers. It should be referred to when reading this section.

6.1. Sensitivity requirements

The 'CARFAX' receiver is designed to be activated only when it is inside the service area of a particular transmitter. The sensitivity of the receiver and aerial need therefore be sufficient only for reliable and satisfactory reception in the minimum field-strength provided within 'CARFAX' service areas. It is expected that the service will be engineered to provide a minimum average field-strength of 1 mV/m, which is relatively high in comparison with the field-strengths for which the average m.f. car radio receiver normally performs satisfactorily.

The transmitted audio modulation will be pre-emphasised and band-limited and both these effects will help in obtaining a higher audio signal-to-noise ratio in the receiver for a given r.f. input signal level (see Section 6.6).

6.2. Aerial requirements

The aerial must be substantially omnidirectional to respond equally to message and ring signals, which usually arrive from different directions; the use of a directional receiving aerial could influence the ratio of message-to-ring signal levels and hence the location of the service area boundary using that aerial. The whip aerial, and the various forms of windscreen disc and horizontal strip aerials, respond to the electric field component, and are found to be sufficiently omnidirectional (to well within 1 dB).[7] They are thus entirely satisfactory for the reception of 'CARFAX' signals.

Even if a second whip aerial is installed for the 'CARFAX' receiver at, say, a distance of one metre, mutual coupling between these aerials would be insufficient to affect each aerial's radiation pattern appreciably.[7]

There are advantages in certain applications in the use of a magnetic receiving aerial, particularly where a 'CARFAX' module is fitted into a domestic portable receiver (see Section 3). The ferrite dipole aerial which is commonly used in such receivers is unsuitable for 'CARFAX' because of its directional properties, but an omnidirectional aerial can be made from a crossed pair of ferrite dipoles whose outputs are summed in quadrature.[8] The quadrature summing, although difficult for a broadband aerial, has been found simple to implement if the aerial is to be dedicated to 'CARFAX' reception, and an experimental version of such an aerial is shown in Fig. 8. Thus the portable receiver might have both this kind of aerial for 'CARFAX', and a conventional ferrite rod aerial for the conventional radio receiver.

Apart from the argument of convenience and small size for the domestic portable application, the use of a magnetic receiving aerial is advantageous for propagation reasons. It is found that the effect of buildings, and indeed trees, on the propagation of m.f. radio waves is to reduce the electric field component considerably more than the magnetic component.[9] The mean electric field intensity will thus drop by, typically, 10 dB in built-up areas, and even more when the receiving aerial is placed inside buildings, whilst the magnetic field intensity remains substantially unchanged. Moreover, minima in the field intensity due to standing-wave effects, are more frequent and severe in the electric component. Of more consequence to the operation of 'CARFAX' is the way in which the ratio may vary of the field-strengths of two co-channel transmissions (ring and message signals) arriving from different directions. Brief tests have shown that, whilst a mean variation of about 4 dB can be experienced in the electric field intensity for a diversity of receiving positions inside a building, the corresponding mean variation in the magnetic field intensity is only about 1·5 dB.*

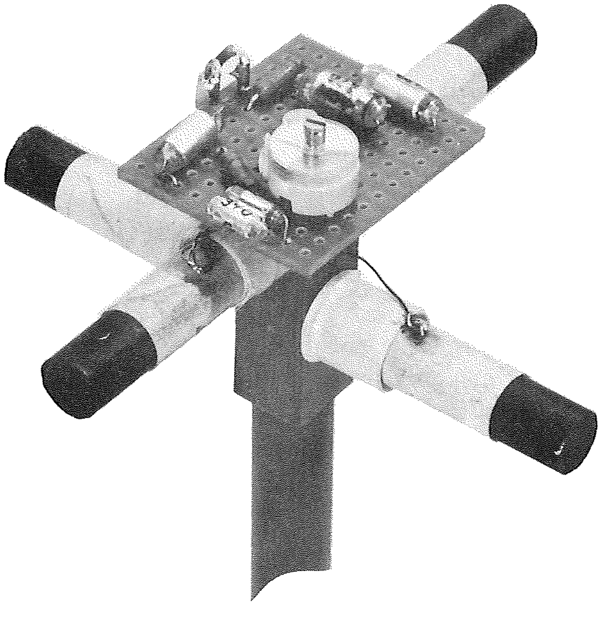

Fig. 8 - An omnidirectional ferrite-rod aerial

Car manufacturers have indicated that the use of steel for car bodywork may soon give way to plastics or fibreglass. Problems associated with the use of an electric receiving aerial may then increase because of increased interference and decreased sensitivity due to the poor or non-existent ground plane provided by the bodywork. The magnetic aerial for both 'CARFAX' and indeed conventional radio reception may then provide a worthwhile alternative for use in cars.

It must be stressed that the ferrite-rod aerial is relatively insensitive compared to a car whip aerial. An omnidirectional ferrite-rod aerial such as that shown in Fig. 8 may be particularly insensitive depending upon the form of the quadrature summing network.

6.3. Aerial splitter requirements

A splitter network is required if both 'CARFAX' and conventional car radio receivers are to share the same aerial. The design of a splitter is made difficult by the high impedance of the car whip aerial at m.f. and l.f. The splitter must pass signals in all the wanted broadcast bands with minimum loss to the conventional receiver, extract the 'CARFAX' frequency, and provide isolation between the output ports so that coupling between the input tuning of the 'CARFAX' and the car radio receivers is reduced to an insignificant value. However, the 'CARFAX' receiver does not need to be particularly sensitive (see Section 6.1), and so it is possible to suffer higher insertion loss at the 'CARFAX' port of the splitter in favour of the port feeding the car radio. Various forms of splitter are suitable and these can be divided into those using active components, and those using only passive ones.

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* More extensive tests using an electric (whip) aerial on a vehicle in typical urban conditions to test the feasibility of the ring system of defining service areas are documented elsewhere.[10]

One form of active splitter consists of a broadband aerial amplifier with two outputs. However, unless the amplifier is placed at the aerial base, this form of splitter is likely to degrade the signal-to-noise ratio of the conventional receiver due to the loss of aerial-tuning Q-magnification. In an alternative form of active splitter, the r.f. signal at the input of the conventional receiver is sampled by a high-input-impedance buffer amplifier, but this form of splitter may be unsatisfactory because it delivers a signal to the 'CARFAX' receiver whose level varies markedly with the input tuning of the conventional receiver. Moreover, all forms of active splitter are prone to overload distortion, and for these reasons a passive splitter is preferred.

A passive splitter can be arranged to introduce very little insertion loss to the conventional radio aerial feed. The passive splitter developed for the prototype receiver, for example, introduces less than 3 dB loss into the conventional receiver feed, and was found to be quite satisfactory in other respects except for the disadvantage of requiring some adjustment during manufacture.

6.4. R.F. amplification and a.m. demodulation

A tuned-radio-frequency (t.r.f.) amplifier (see Section 4) which provides adequate selectivity is recommended. A good a.g.c. response is also necessary to minimise unwanted variations in the difference in loudness between normal listening and the traffic messages.

Integrated circuits intended for superheterodyne receivers are readily available and can be adapted for use in a t.r.f. receiver but, at present, it is thought that a cheaper alternative is to use discrete semiconductors. However, in the longer term, an integrated circuit could be custom-designed to include r.f. amplification and both a.m. and f.m. signal-demodulating circuits, giving a substantial reduction in cost and size.

6.5. Selectivity and adjacent-channel interference

Better selectivity can be obtained using an inexpensive ceramic filter unit, similar to those used for i.f. filters in some domestic radio receivers. Such filters are at present manufactured only for popular i.f. applications and do not necessarily have the required long-term tuning stability. However, it is understood that the technology exists for the manufacture of such filters with a suitable performance.

The selectivity required is difficult to define in the long term, due to the uncertainty of the nature of channel that would be allocated for a service such as 'CARFAX'. It is hoped that a clear channel possibly outside the normal broadcast band around 500 kHz will eventually be allocated. Given a clear channel (i.e. one free from co-channel interference from other services), the problem of adjacent-channel interference remains.* However, measurements have shown that advantage can be taken of the narrow bandwidth occupied by the 'CARFAX' signal combined with the highly selective properties of inexpensive ceramic filters, to improve resistance to adjacent-channel interference by about 10 dB, relative to normal m.f. conditions.

6.6. Audio de-emphasis

The transmitted speech modulation is pre-emphasised using a time-constant of 150 μs. Such a high value of pre-emphasis time-constant may be used only because the message signal consists substantially of speech, the spectral power density of which falls markedly above about 1 kHz. Pre-emphasis both improves the resistance to adjacent-channel interference and makes it easier to obtain an adequate signal-to-noise ratio at the receiver output. A complementary de-emphasis circuit is thus needed in the receiver and this is specified in the Appendix and included in the circuit diagram of Fig. 7.

6.7. F.M. demodulation and capture-effect

An f.m. demodulator is required for reception of the START and FINISH signals which activate and de-activate the receiver, respectively. The performance of this demodulator is not particularly critical, and the many integrated circuit devices intended for f.m. sound receivers are more than adequate for this application. It is, however, important that the limiter provides adequate a.m. rejection so that the START and FINISH detectors are protected against false operation by the a.m. message modulation which may have values up to a depth of 95%. The f.m. demodulator must also have a good (low) capture ratio. Capture ratio is a measure of the abruptness of f.m. capture effect and it is this which determines the location of the boundaries of the 'CARFAX' service areas.[4,5] Capture ratio is measured as the change in the ratio of the levels of two r.f. input signals, one modulated and the other unmodulated, necessary to produce a prescribed change in the level of the demodulated output signal.

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* The temporary channel allocated for the field trial will be prone to adjacent-channel interference at night-time due to continental transmissions at +4·5 kHz.

In the receiver, non-ideal capture effect is caused by excessive selectivity or bandwidth restriction either before or after limiting, and/or insufficient limiting; the effect of the latter will not be great provided adequate a.m. rejection has been achieved. Sharp selectivity before limiting tends to produce f.m. to a.m. conversion, and this results in both a modulation of the ratio of message-to-ring carrier levels with corresponding loss of definition in the capture effect, and a reduction in the mean of the ratio of carrier levels. Both effects can be important and the r.f. response should be maintained reasonably flat over ±2 kHz (see Section 9.6). Bandwidth restriction can also occur after limiting, for instance, in the quadrature tuned circuit, and experience shows that a peak-to-peak discriminator bandwidth of more than about 15 kHz ensures satisfactory operation here.[4,6]

A fourth aspect of the f.m. demodulator, and indeed the circuits following it, which is of importance is its output gain stability. The receiver should respond to START signals only if their average level after demodulation exceeds a certain 'receiver activation threshold level'. This level should be stable within the limits set in the Appendix (Section 9.8). The reason for this is as follows. Capture effect ensures, normally, that the locations of the service area boundaries are virtually independent of the receiver activation threshold level. However, in some areas, more than one ring signal may have a significant level and capture effect then becomes less pronounced.[5,6] In these areas, the threshold level must be more closely defined to retain the accurate definition of service area boundaries.

6.8. START and FINISH signal detection

The START and FINISH detectors must respond unambiguously to 125 Hz and 200 Hz frequency-modulation, respectively, for peak deviations exceeding certain threshold values defined in the Appendix (Sections 9.8 and 9.9). The frequency and amplitude characteristics of the detectors must be stable, but the limits set are probably sufficiently wide to permit the design of receivers with no preset adjustments in these areas.

The use of active bandpass filters is perhaps the simplest approach, and Q-factors of between about 7 and 15 are found to be suitable. The choice of modulation frequencies for the START and FINISH signals of 1 kHz divided by 8 and 5 respectively, means that a simple phase-locked-loop technique may be used in detecting these signals.

6.9. Latching

The 'CARFAX' receiver should become activated preferably *after* the reception of a START signal, to prevent the START signal being heard. The reason for this is as follows. Due to f.m. to a.m. conversion effects, the f.m. START and FINISH signals can give rise to an audible output from an activated 'CARFAX' receiver. The effect is not found to be unpleasant, except in the case of START signals received in the presence of ring signals of significant level, an occurrence which can be quite common (see Section 9.10).

The receiver should be designed to become de-activated within a fraction of a second after the beginning of a FINISH signal, but not too early in order to make proper use of the FINISH burst-length transmitted (see Section 9.10).

6.10. Audio changeover switching

It has been found desirable for the audio switch to give a cross-fade rather than an abrupt changeover between the motorists ordinary listening and a 'CARFAX' message. It is important that the audio switch be designed so as not to impair the ordinary listening signal whilst the 'CARFAX' receiver is quiescent, whether by introducing distortion, degrading the signal-to-noise ratio, or incurring crosstalk from the traffic receiver. The performance need not be as critical when the switch is in the message position, and during the cross-fade itself a measure of distortion has been found permissible.

7. Conclusions

The requirements of the special receiver required for the proposed 'CARFAX' traffic information service have been discussed, both in the light of experience gained in the development of the transmission system proposed and in the design of a prototype receiver used in that development. The performance requirements are given in Appendix I.

The Report demonstrates the simplicity and low cost of receivers for the 'CARFAX' service, and the ease with which the 'CARFAX' receiving facility could be incorporated in future radio receiver designs.

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9. Appendix I

Receiver performance requirements

9.1. Test conditions

All the performance requirements described below, with the possible exception of r.f. selectivity, can be checked in terms of the r.f. signal input and the audio signal output.

9.1.1. R.F. signal input

For test purposes, the r.f. input signal to the aerial is provided by a dummy aerial circuit fed from a signal generator as shown in Fig. 9. The effective source impedance of the signal generator should be less than 100Ω. The r.f. input signal level quoted is the voltage v_w at the input terminals of the dummy aerial when it is connected to the receiver. If the receiver includes an aerial trimming adjustment, this must be correctly set for the dummy aerial.

9.1.2. Reference audio output level

The audio output level must be measured at the output of the 'CARFAX' receiver when activated, unless otherwise stated. In these performance requirements the audio output reference level (0 dB ref) is defined as the output level into a normal load with an r.f. input level of 50 dBμV, amplitude-modulated to a depth of 30% by 500 Hz tone.

9.2. Aerial system

9.2.1. The requirements relate to a 'CARFAX' receiver intended to be fed from a conventional car aerial.*

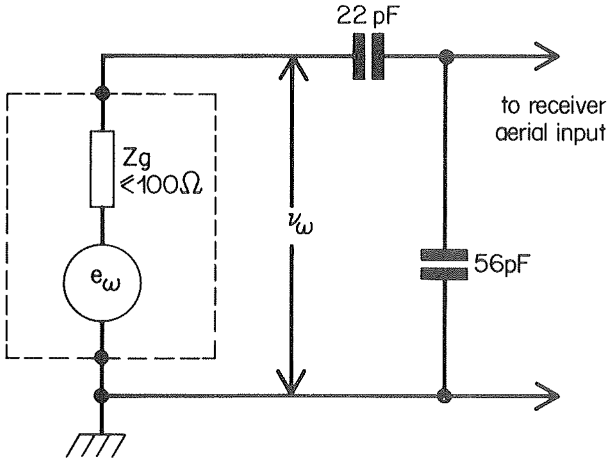

Fig. 9 - Dummy aerial circuit

The requirements of a 'CARFAX' receiver fitted within a domestic portable radio receiver would be similar, except in regard to the aerial circuits, and the way in which the input signal level is defined. This matter is dealt with more fully elsewhere.[6]

9.2.2. For an integrated or add-on type of receiver, an aerial splitting system should be provided so that the 'CARFAX' unit and the normal car radio can share a single aerial. The attenuation in the two paths of the splitter should be determined by the receiver designer within the framework of the performance requirements of each receiver. The design of this splitter should allow the normal radio to be tuned through the 'CARFAX' carrier frequency, with a change in the sensitivity of the 'CARFAX' receiver of less than 10 dB. However, in making performance test measurements on a 'CARFAX' receiver, any conventional receiver sharing the same aerial input should be tuned well away from the 'CARFAX' frequency.

9.3. Carrier frequency

The receiver shall be fixed-tuned to 526·5 kHz and remain stable in tuning (±1 kHz) over the specified range of supply voltages and ambient temperatures (see Sections 9.12 and 9.13). (The above carrier frequency will probably be changed after the field trial, but it is hoped that the final frequency will be within receiver re-alignment range of 526·5 kHz.)

9.4. A.M. sensitivity

The r.m.s. audio noise output level (after de-emphasis) with an unmodulated r.f. input signal at a level of 40 dBμV shall not exceed −22·5 dB ref.

9.5. A.G.C. (Fig. 10)

9.5.1. The audio output signal level, with an r.f. input signal level of 40 dBμV, amplitude-modulated to a depth of 30% by 500 Hz tone, shall exceed −5 dB ref.

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* The aerial must be substantially omnidirectional (within ±1 dB) at m.f.. as is found to be the case for most car aerial configurations available.

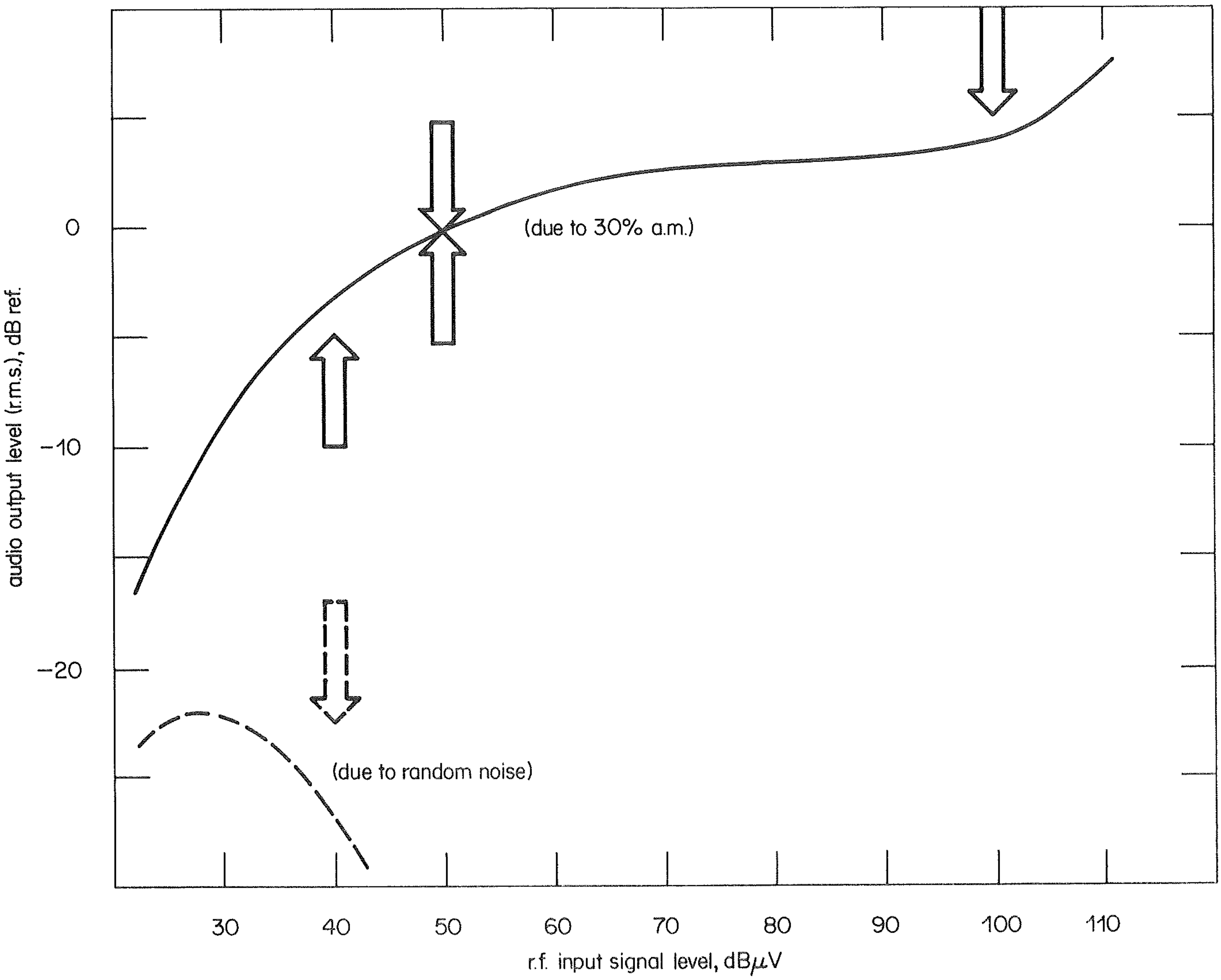

Fig. 10 - A.M. sensitivity and a.g.c. limits

——— Performance of typical receiver, with carrier modulated to 30%

— — Performance of typical receiver, with carrier unmodulated

9.5.2. The audio output signal level, with an r.f. input signal level of 100 dBμV, amplitude-modulated to a depth of 30% by 500 Hz tone, shall not exceed +5 dB ref.

9.6. R.F. selectivity (Fig. 11)

The r.f. selectivity shall be such that r.f. signals spaced from the nominal carrier frequency shall be attenuated as follows:

Spacing from carrier	Attenuation
±2 kHz	< 3 dB
±9 kHz	>20 dB
±18 kHz	>40 dB

(It is possible that the selectivity requirements may be changed to provide a response much closer to the ideal rectangular characteristic than that above. This is highly desirable and is feasible because inexpensive ceramic filters meeting the new response are now becoming available. (Measurements show that the consequent improvement in selectivity can typically give a 10 dB increase in protection from interference from an adjacent channel, 9 kHz from the 'CARFAX' channel, compared with conventional circuits.))

9.7. Overall modulation response (Fig. 12)

With an r.f. input signal level of 50 dBμV, amplitude-modulated to a depth of 30%, the change of audio output signal level with modulating frequency should be within the following limits. (Note that this response includes the effect of de-emphasis with a time constant of 150 μs.)

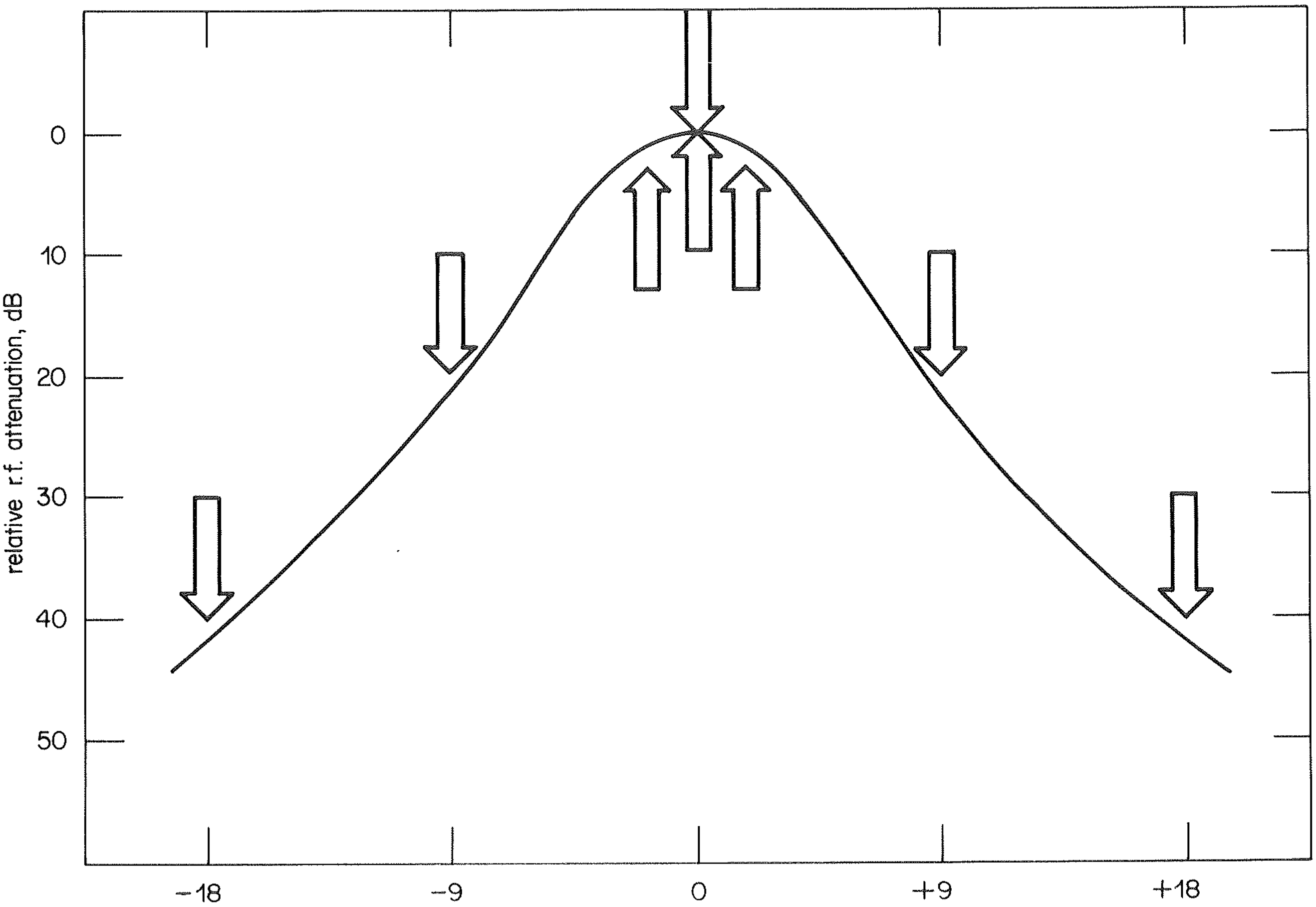

Fig. 11 - R.F. selectivity limits

——— Performance of typical receiver

500 Hz	0 dB ref (reference)
100 Hz	minimum value −5 dB ref
2 kHz	between −7½ dB ref and −2½ dB ref
3 kHz	minimum value −12½ dB ref
>5 kHz	maximum value −17½ dB ref

9.8. Capture effect and START coded signal reception

For these tests, two r.f. signals are applied to the receiver via the dummy aerial circuit. The two signal generators e_w and e_i must be effectively connected in series as shown in Fig. 13 and the source impedance of the combined generators should be less than 100 Ω. It should be possible to define accurately the ratio v_w/v_i of the r.f. signal levels at the input terminals of the dummy aerial. The signal v_w represents a wanted carrier level which should be set to about 50 dBμV. It should be possible to frequency-modulate this carrier with bursts of sinusoidal tone; any amplitude-modulation should be less than 5%. The second carrier v_i represents an interfering 'CARFAX' carrier which should be unmodulated and with a level variable from zero to 110 dBμV.

9.8.1. (Fig. 14) In the absence of an interfering carrier and with continuous* frequency-modulation of the wanted carrier by 125 Hz tone, the receiver shall respond as if to a START signal (i.e. become activated) for peak f.m. deviations of greater than ±0·9 kHz. The receiver shall not respond for peak deviation less than ±0·7 kHz.**

9.8.2. In the absence of an interfering carrier and with an f.m. burst duration of 0·8 s, the receiver shall respond as if to a START signal for peak f.m. deviations greater than ±1·0 kHz at 125 Hz.**

9.8.3. (Fig. 14) With an f.m. burst duration of 0·8 s and a peak f.m. deviation of ±1·5 kHz at 125 Hz, the receiver shall respond as if to a START signal when the wanted carrier exceeds the interfering carrier by more than 1·5 dB. With the same f.m. burst duration of 0·8 s, but with a peak f.m.

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* A burst of duration ⩾1·5 s is sufficiently close to 'continuous' for the purposes of this test.

** For prototype receivers, it may be preferable for these parameters to be adjustable.

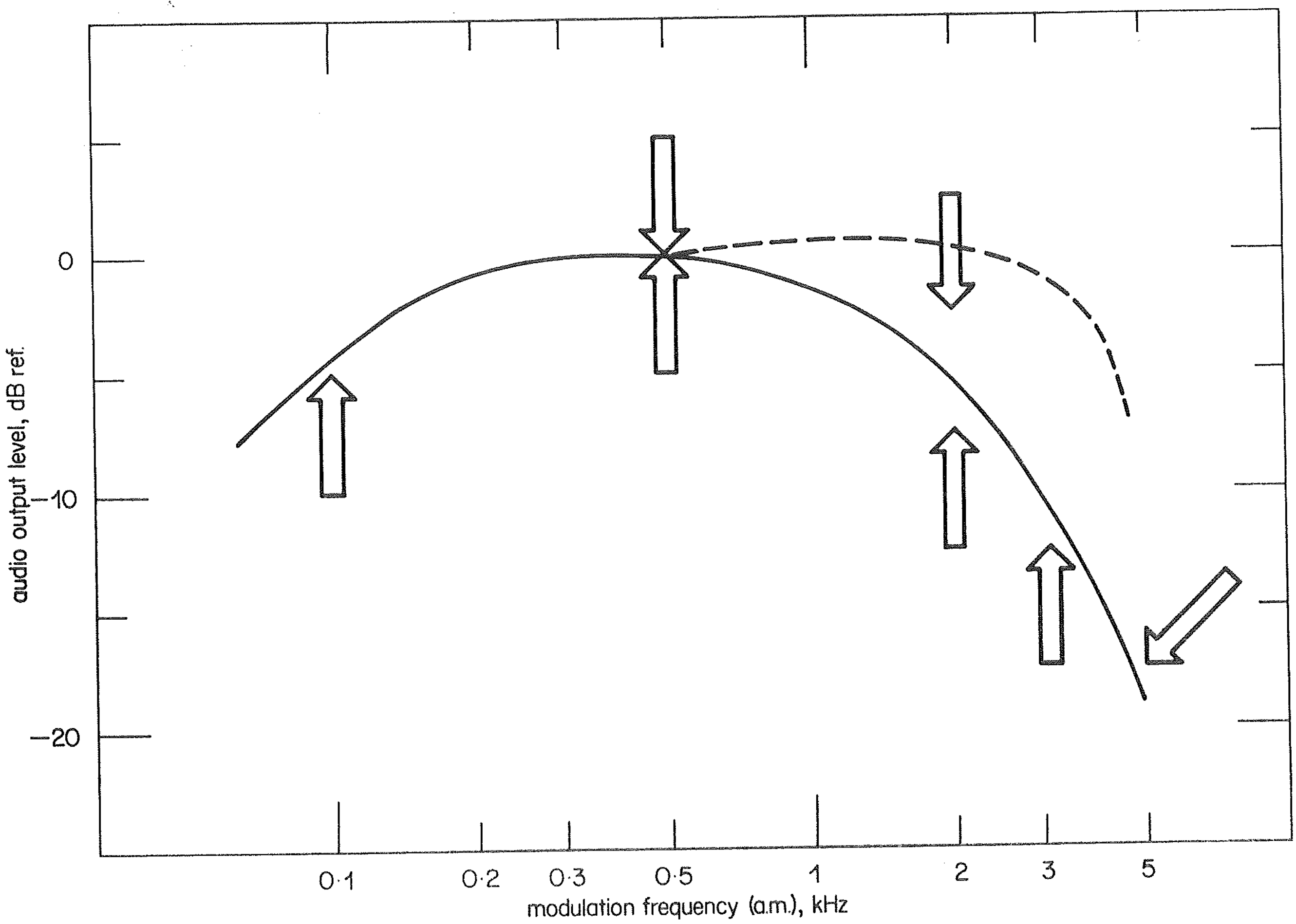

Fig. 12 - Overall modulation response limits

——— Performance of typical receiver — — — As above, only showing 'top-lift' due to 150 μs pre-emphasis

deviation of ±2·5 kHz, the receiver shall not respond when the level of the interfering carrier exceeds that of the wanted carrier by more than 0·5 dB. These parameters effectively define the capture ratio.

9.8.4. (Fig. 15) In the absence of an interfering carrier, and with a peak f.m. deviation of the wanted carrier of ±2 kHz and a burst duration of 0·8 s, the receiver shall not respond as if to a START signal for modulation frequencies below 100 Hz or above 160 Hz.

9.9. FINISH coded signal reception

9.9.1. (Fig. 16) With an r.f. input level of about 50 dBμV and continuous frequency-modulation by 200 Hz tone and with no interfering carrier, the receiver shall respond as if to a FINISH signal (i.e. become de-activated) for peak f.m. deviations greater than ±1·1 kHz. The receiver shall not operate for peak deviations less than ±0·4 kHz.

9.9.2. With an r.f. input signal level of about 50 dBμV and an f.m. burst duration of 0·5 s and with no interfering carrier, the receiver shall respond as if to a FINISH signal for peak deviations greater than ±1·3 kHz at 200 Hz.

9.9.3. (Fig. 16) With an f.m. burst duration of 0·5 s and a peak f.m. deviation of ±2 kHz at 200 Hz and with no interfering carrier, the receiver shall respond as if to a FINISH signal for any r.f. signal level in the range 30 dBμV to 110 dBμV.

9.9.4. (Fig. 15) For a peak f.m. deviation of ±2 kHz and a burst duration of 0·5 s, the receiver shall not respond as if to a FINISH signal for modulation frequencies below 160 Hz or above 250 Hz.

9.10. Latching

9.10.1. When first switched on, the receiver shall assume the de-activated condition automatically.

9.10.2. On reception of a START or FINISH signal, the receiver shall latch or unlatch, respec-

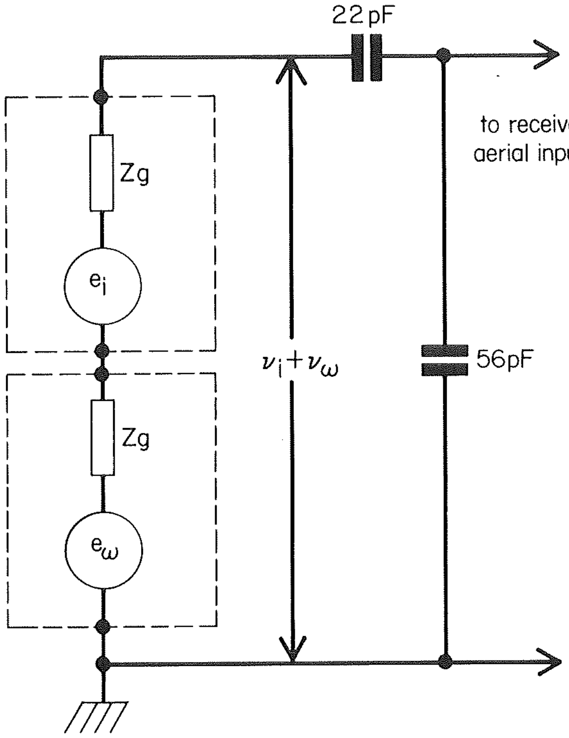

Fig. 13 - Dummy aerial circuit for Section 9.8

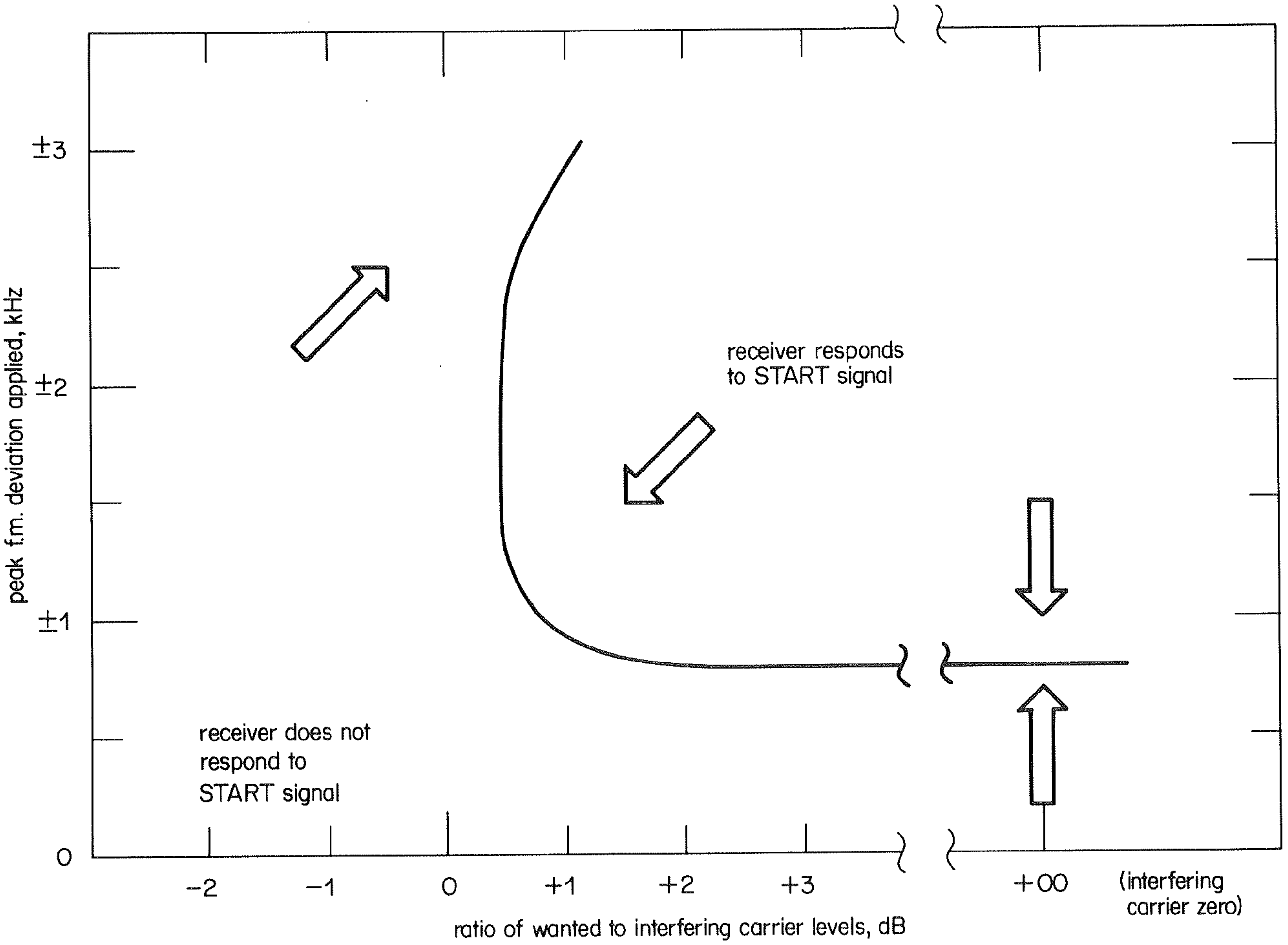

Fig. 14 - START signal reception limits and capture effect

——— Characteristic of typical receiver to normal START signals

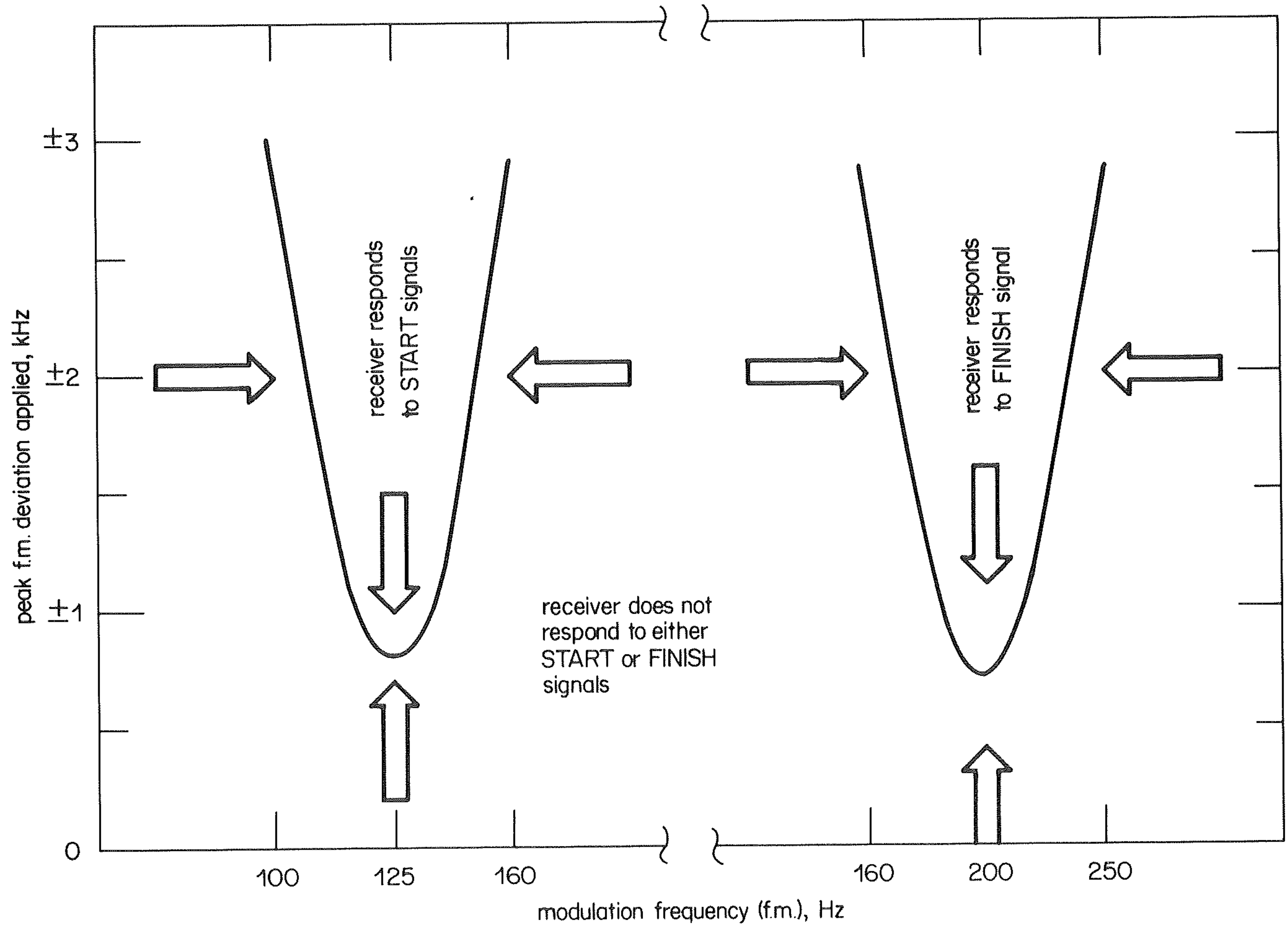

Fig. 15 - Frequency limits for START/FINISH reception

——— Characteristic of typical receiver to normal START and FINISH signals

tively, and thereafter remain in the designated condition unless intentionally overridden. The receiver shall not change its condition for any other reason or combination of reasons, for example due to message modulation, low r.f. input signal levels, operation with the dummy aerial circuit disconnected from the receiver, or normal supply line fluctuations (see Section 9.12.2).

9.10.3. In particular, the receiver should not respond either as if to a START signal, or as if to a FINISH signal, for 95% amplitude-modulation of the carrier at 125 Hz or 200 Hz.

9.10.4. It should be possible to reset manually the latch to its de-activated state.

9.10.5. The change to the activated condition should be completed within 1 s after the end of the START signal. The change to the de-activated condition should be completed within 0·5 s after the beginning of the FINISH signal.

9.10.6. For both add-on or integrated receivers, three listening options should be selectable by the user as follows:

1. ordinary listening without interruptions by traffic announcements
2. ordinary listening interrupted by local traffic announcements when they occur
3. traffic announcements only, with silence in between.

The simplest form of stand-alone receiver would provide only the third option.

Ordinary listening is defined as whatever audio signal the other parts of the installation may provide, such as normal radio programme or the output from a stereo cassette player.

9.10.7. It is recommended that a visual indication of receiver activation should be provided, e.g. a 'CARFAX' pilot lamp.

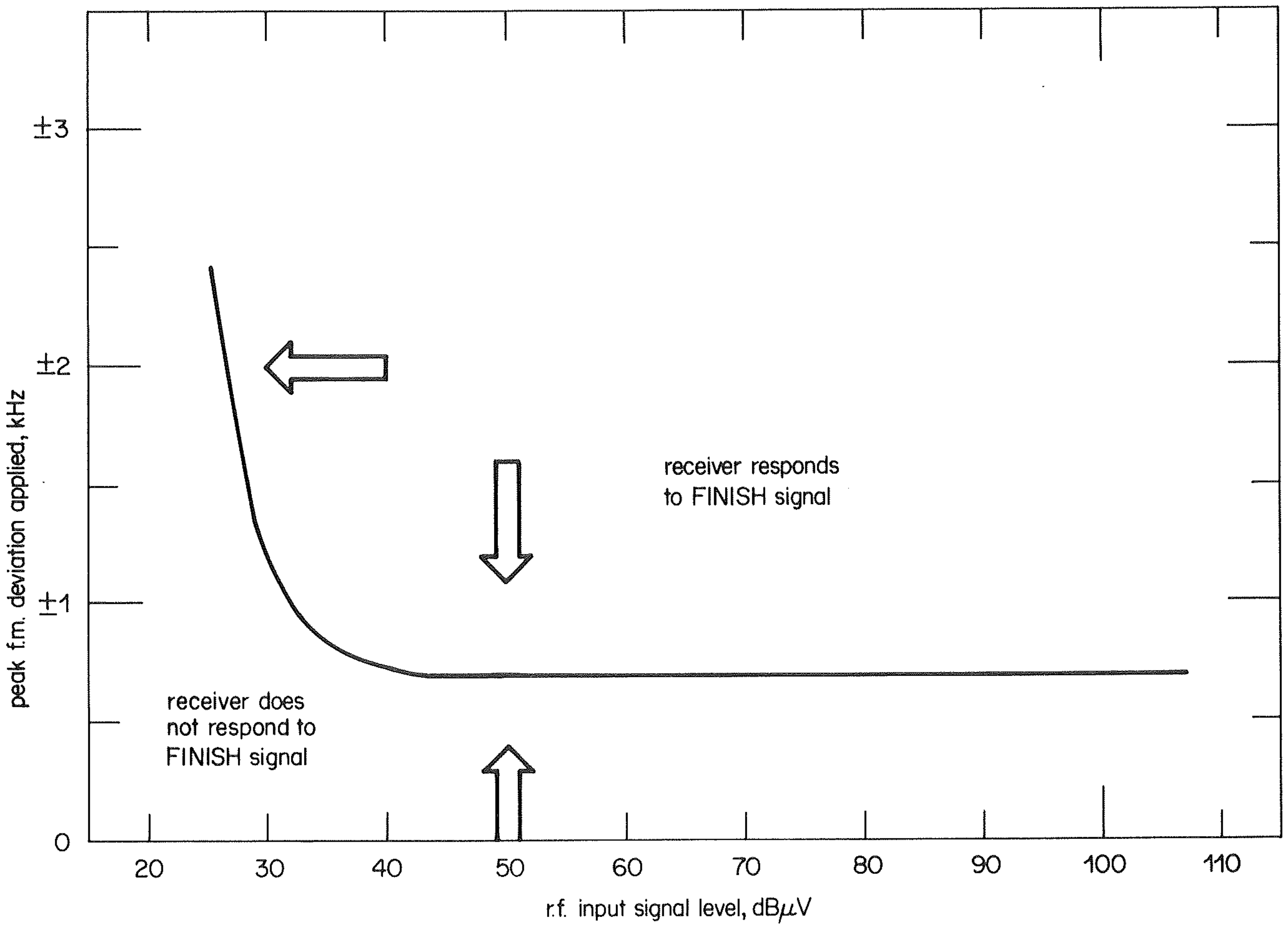

Fig. 16 - FINISH signal reception limits

——— Characteristic of typical receiver to normal FINISH signals

9.11. Audio switching

9.11.1. The automatic audio-switch shall mute the output from the message demodulator by more than 40 dB when the receiver is 'de-activated' (i.e. after reception of a FINISH signal).

9.11.2. The automatic switching should not introduce annoying transients such as clicks into the audio output of the receiver. It is recommended that, if the 'CARFAX' receiver is capable of interrupting the motorist's ordinary lisenting, the changeover between ordinary listening and traffic messages should be in the form of a cross-fade so as to avoid an abrupt change.

9.11.3. If the 'CARFAX' receiver is integrated with a conventional receiver, and no user control is fitted to vary the relative audio levels of the two receivers, those levels shall be matched as follows. For an r.f. signal level of 50 dBμV at, say, 1 MHz, to which the conventional receiver is tuned, and with amplitude-modulation of this signal to a depth of 30% by 500 Hz tone, the audio output level when the 'CARFAX' receiver is de-activated shall be in the range −2·5 dB to +2·5 dB with respect to the 'CARFAX' reference level.

9.12. Supply voltage

9.12.1. All the foregoing performance requirements shall be met over a supply voltage range from 12 V d.c. to 15 V d.c. It is thought that items 9.8.1. and 9.9.1. will be the most susceptible to supply voltage variations.

9.12.2. The receiver shall not respond as if to a START or FINISH signal in the presence of 0·5 V peak-to-peak ripple on the supply line at either 125 Hz or 200 Hz.

9.12.3. The receiver shall operate moderately well over a supply voltage range from 11 V to 16 V.

9.13. Temperature

9.13.1. All the foregoing specification shall be met over an ambient temperature range from 0°C to 40°C. It is thought that item 9.3 will be the most susceptible to temperature variations.

9.13.2. The receiver shall operate moderately well over the temperature range $-20°$C to $+60°$C.

9.14. Construction

The traffic information receiver shall be manufactured to the usual car radio standards, in particular with regard to screening and immunity from interference and microphony. Interference from the vehicle itself, particularly that borne by the power supply lines, should be guarded against.

10. Appendix II

10.1. Winding details for the prototype receiver coil assemblies

T1	Primary 3 turns swg 30, secondary 3 turns swg 30, wound on ferrite bead type FX 1115.
T2 – T7	Wound on Neosid K2 coil assembly formers, with slug, shell and can. The sections are listed in the order in which they should be wound. The asterisk * in the circuit diagram, Fig. 7, denotes the beginning of the winding.
T2	Secondary 34 turns swg 45, interwinding insulation to reduce the interwinding capacitance to less than 15 pF, primary 246 turns swg 45.
T3	Secondary 3 turns swg 37, primary 104 turns swg 42.
T4	102 turns swg 42, with tap at 20 turns.
T5	104 turns swg 42, with tap at 50 turns.
T6	Secondary 7 turns swg 37, primary 104 turns swg 42.
T7	90 turns swg 39.

10.2. The passive aerial splitter

The splitter is designed to divide the aerial signal between two output ports which are themselves isolated from each other. A hybrid transformer would provide the required function[11] but, because of design difficulties relating to the high characteristic-impedance of a car aerial at medium and low frequencies, the circuit employed in Fig. 7 is more practicable.

The isolation and splitting properties of the splitter are best understood by redrawing it as a bridge circuit. Fig. 17 shows the aerial splitter used in prototype receiver redrawn in this way. The v.h.f. by-pass transformer T1 shown in Fig. 7 is not an essential part of the splitter and is not shown here.

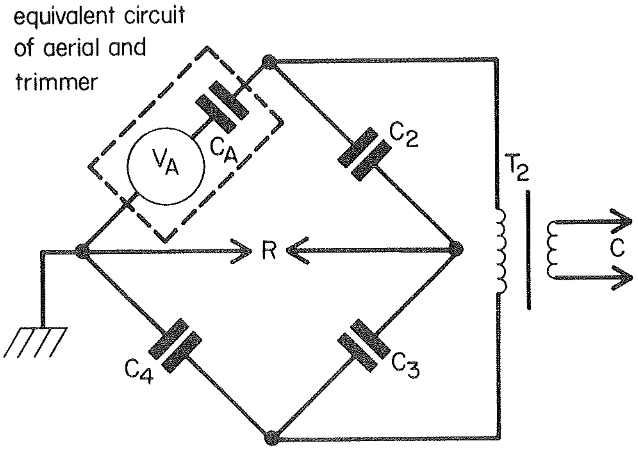

Fig. 17 - The aerial splitter redrawn as a bridge circuit

At m.f. and l.f., a car whip aerial, of height h, approximates to a monopole above a ground plane with an equivalent circuit as shown in Fig. 18(*a*), which also includes the trimmer capacitance. With reference to Fig. 18(*a*), the e.m.f. V_e regenerated in the presence of an electric field strength E (vertical polarisation) can be shown to be given by

$$V_e = \tfrac{1}{2}hE,$$

and the source impedance can be shown to comprise the radiation resistance r, which is negligible at m.f. and l.f., and the self-capacitance C_s, typically about 9 pF for a 0·8 m whip aerial.[8] C_f is the capacitance of the aerial feeder.

Most car radio receivers utilise permeability tuning in which the first r.f. tuning coil resonates with the aerial and feeder capacitance. The purpose of the aerial trimmer capacitance is to trim the total capacitance to that for which the tuned-circuit was designed (usually about 150 pF) so as to accommodate various aerial and feeder capacitances. The equivalent circuit can thus be

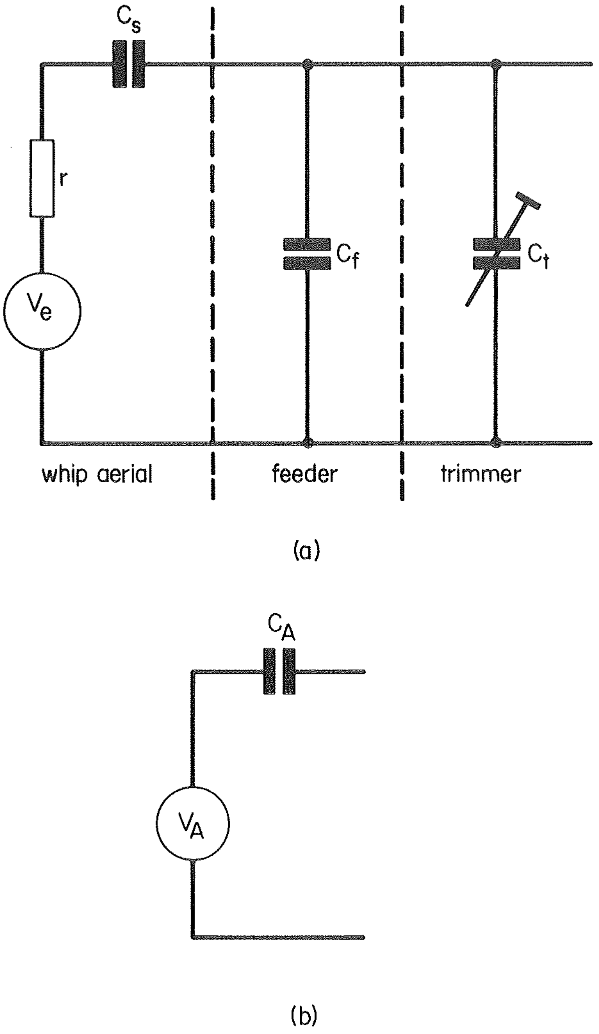

Fig. 18 - Equivalent circuit of a car aerial, feeder and trimmer
(*a*) detailed (*b*) simplfied

simplified to that shown in Fig. 18(*b*) where C_A = 150 pF, as above, and the source voltage V_A is a potentially divided version of V_e, i.e.

$$V_A = \frac{C_s}{C_A} V_e$$

Returning to the splitter shown in Fig. 17, isolation between the output ports labelled R and C is obtained when the bridge is balanced, i.e.

$$\frac{C_2}{C_3} = \frac{C_A}{C_4} = n$$

It can then be shown that the parameter n is the voltage-splitting ratio between ports R and C so that, in the case where the output impedance Z_R of the R port equals the source impedance due to C_A (which is required so that the splitter does not affect the tuning of the car radio receiver)

i.e. $$Z_R = \frac{1}{j\omega C_A},$$

then $$Z_C = Z_R$$

$$C_2 = nC_A$$

$$V_R = \frac{n}{n+1} V_A$$

and $$V_C = \frac{1}{n+1} V_A$$

where each output port is equivalent to a voltage source of V_R (or V_C) in series with an impedance of Z_R (or Z_C).

The purpose of the transformer T2 in Fig. 7 and 17 is three-fold. Firstly, it provides an unbalanced output and, secondly, it provides a suitable impedance-transformation to match into the first stage of the 'CARFAX' receiver. Lastly, the inductance of its primary winding is arranged to resonate at the 'CARFAX' channel frequency with the capacitive source impedance provided by the splitter, thus providing aerial tuning for the 'CARFAX' receiver.

The voltage-splitting ratio n is chosen so as to attenuate as little as possible the signal fed to the car radio receiver commensurate with the relatively low sensitivity required of the 'CARFAX' receiver. The value of n = 3 adopted in the prototype receiver results in an insertion loss of 2·5 dB in the feed to the car radio receiver.

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